DOCUMENT RESUME

ED 403 132 SE 059 586

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TITLE Public Understanding of Science as Seen by the Scientific Community: Do We Need To Re-Conceptualize the Challenge and To Re-Examine Our Own Assumptions?

PUB DATE 18 Nov 96

NOTE 25p.; Paper presented at the Seminar for Science, Technology and Citizenship (Leangkollen, Norway, November 18-19, 1996).

PUB TYPE Speeches/Conference Papers (150) -- Viewpoints (Opinion/Position Papers, Essays, etc.) (120)

EDRS PRICE MF01/PC01 Plus Postage.

DESCRIPTORS Educational Change; Elementary Secondary Education; Futures (of Society); Higher Education; *Public Opinion; *Science and Society; Science Education; Scientific Literacy; Scientists; Values

IDENTIFIERS *Philosophy of Science

ABSTRACT

This paper addresses the question of how the scientific community views the public understanding of science and whether there needs to be a re-conceptualization of the challenge to foster the public understanding of science, as well as whether there is a need to re-examine assumptions. It is argued that the science community's historic perspective on the public is grounded in the legitimate interests of science, but that the promotion of the public understanding of science needs to be grounded in its legitimate interests in science. Topics covered include: (1) A Celebration of Science, which discusses angst in the scientific community and heroic stories of scientific investigations; (2) Anti-Science Sentiment, a phenomenon of the last 20 years; (3) Scientific Positivism, which roughly represents a classical view of realism, philosophical materialism, strict objectivity, and hypothetico-deductive method; and (4) An Alternative View of Science and the Public, where the differences between scientists' and nonscientists' views of nature and problems with the compatibility of science with very different perspectives is explained. It is concluded that the science community and school science education must locate science within a broader view of knowledge. Contains 62 references. (PVD)

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Public Understanding of Science as Seen by the Scientific Community: Do We Need to Re-Conceptualize the Challenge and to Re-Examine Our Own Assumptions?

Paper presented at the seminar for Science, Technology and Citizenship, 18-19 November 1996, Leangkollen, Norway.

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Introductory Remarks

My task is to address the question of how the scientific community views the public understanding of science and whether there needs to be a re-conceptualization of the challenge to foster the public understanding of science, and also whether there is a need to re-examine assumptions. I am compelled to begin by acknowledging a debt to an important book, *Inarticulate Science*, written by Edgar Jenkins and his colleagues at Leeds. *Inarticulate Science* is an outstanding contribution on the concept of the public understanding of science and I think of my contribution today on this topic as a footnote. My perspective is somewhat different in that I have school settings in mind rather than adult learning (also see Lewenstein, 1992). I want to address the question of how the science community should think about the public understanding of science with respect to what happens in schools; and by school I mean K-12 school plus the undergraduate science education of non science university majors. Also, I make my remarks from a cultural perspective in that I think it is important to think about how scientific ideas contribute to and influence the worldviews we construct for ourselves. Specifically, I am interested in science as an aspect of different systems of meaning that people construct for making sense of their worlds: "An aspect" of meaning because science is not the entire ball game except for a few people who chose to elevate science to the level of metaphysics; "different systems" because even among scientists there are differences as to how science is used in the construction of meaning.

I also want to preface my remarks by noting that I am of course speaking from my experiences as an American science educator. What is happening in the USA, however, does not appear to be unique (see Gaskell, 1996; Sjorberg, 1996). For example, several industrial nations including Norway are involved in the Third International Mathematics and Science Study (National Research Council, 1996) for what appear to be the same reasons. UNESCO is promoting Project 2000+ which has a parallel form in the USA. The slogan "Science for All" can be heard worldwide; but, I also think that given the enormous size of the American scientific and education establishments along with publishing interests that what happens in the USA can hardly go unnoticed or unfelt. Nonetheless I will be at pains not to appear overly Yankee-centric.

The structure of my remarks will be as follows. I begin with a celebration of science but then move on to discuss what concerns the scientific community has about the public. From here I address the key problematic element within the scientific community itself, the epistemology of scientific positivism. This epistemology creates considerable difficulties for the community of science within the public square.[1]

Finally, I begin with the end. Let me say at the onset where I am headed. Yes, the science community does need to re conceptualize the challenge and re-examine its assumptions about the public understanding of science. The science community's historic perspective on the public is grounded in the legitimate interests of science; but, the promotion of the public understanding of science needs to be grounded in the public's legitimate interests in science. The distinction between the prepositions "of" and "in" is crucial and I owe this insight to physicist Martin Eger (1989). Eger's distinction is similar to Ziman's (1984, 1991, 1992) science insiders and outsiders, which was also adopted by Jenkins (1992) and Layton et al (1993).

A Celebration of Science

What is the "scientific community?" Ask a scientist and he or she is likely to say that the community of science is composed of the science departments and science laboratories at universities and research institutions. This community surely includes scientific journals and professional societies and meetings. We might also be able to agree that university science textbooks serve as a kind of unofficial canon for the scientific community. Above all these, the people we call scientists form the scientific community. I do not think it is helpful to think of science as something separate from the people who construct, write about, teach or learn scientific knowledge. Regarding the scientific community, we live at a time when that community finds itself in the throes of considerable angst. It is an angst not only about the public's apparent lack of scientific understanding but also about an apparent lack of public esteem for science and scientific ways of thinking.

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[1] The term "public square" is a metaphor based on the concept of a town square and was coined by Neuhaus (1984).

Paradoxically this angst is being endured at the same time that government agencies are pursuing another round of science education reforms for the improvement of science learning. In the USA, the National Science Teachers Association (NSTA) and the American Association for the Advancement of Science (AAAS) have proposed new science curriculum frameworks. There is a new set of national science standards promoted by the National Academy of Science (NAS) and endorsed by both NSTA and AAAS. NAS and AAAS are organizations clearly within the boundaries of the scientific community and though NSTA is a teachers organization, it is an organization closely related to the community of science. Hence the efforts of these organizations strongly reflect the interests of the scientific community. Yet there is this angst evident by the recent spate of literature scientists and fellow travelers have written to explore the problem of "anti science" (e.g., Bishop, 1995; Crease, 1089; Durant, 1990; Dyson, 1993; Gross & Levitt, 1993; Holton, 1993; Ruse, 1994; Theocharis & Psimopoulos, 1987). That this literature strikes a resonant chord within the community of science is evident from the laudatory reviews and letters to the editor published in the mainline scientific press. My position will be that the angst is well founded but the description of the problem is wholly wrong headed. To paraphrase the words of Pogo, a famous cartoon character, the science community should be saying "we have met the enemy and he is us!"

This seems a very negative remark but I am not launching another round of science bashing. In fact I want to move quickly now to a celebratory stance. There is much in science to celebrate. I personally cannot think of a time when I was not interested in science. Typical of many students I do not remember much science being taught in my elementary grade classrooms. What I remember is the power and the wonder of the Pacific Ocean to the west of our home and the majesty of the Sierra Nevada mountains to the east. I recall the fascination of flight whether the flight of birds or of airplanes. I remember being glued to the television set through the great events of the Apollo missions. From junior high school on I do remember my science classes. Not because my science teachers were exceptional. They were not. I do not recall ever having a science teacher I would call an exceptional teacher whereas I clearly recall a high school English teacher who was a superb teacher. As research has shown there are students who seem almost naturally drawn to science; and it appears to matter little what happens in school science, these science enthusiasts continue inexorably

along the scientific pathway (see Costa, 1993, 1995). School science is a *de facto* natural selection device for screening the majority of students out of science (West, 1996).

I admit to having mixed feelings about my experiences as a university student but more than anything else that has to do with the time period. It was the late sixties - the height of the Viet Nam War - and it was difficult to be a university student at a time of national crisis. But if I think only of my science studies I have to say it was a heady experience. Take for example the long laborious and grueling hours spent in a *Drosophila* laboratory working out genetic arrangements and chromosomal structures for fruit flies. To my friends in other disciplines this was certainly the best example of a silly and boring use of one's time. I can only describe the experience as heady because we were actually working out the physical mechanisms that made the particular fruit fly look they way it did. And then to actually photograph the chromosomes, what a thrilling experience! A year later we took the next step and actually extracted DNA. Again, what a thrilling experience not only to know nature at such a fundamental level, but to touch nature at such a fundamental level. At the time of these experiences we also met some of the great stars of scientific research. I had the honor of studying biology with Paul Saltman and physical chemistry with Stanley Miller. We had guest lectures by Gunther Stent and Max Delbrück. Who needs Mel Gibson when you have just been to a lecture by Linus Pauling? Perhaps this is hyperbole but these experiences lend themselves to positive exaggeration — at least for the science enthusiast.

Indeed, the heroic stories of scientific investigations were almost as good as any film. One story that has long fascinated me is the story of identifying the DNA synthesis enzyme because it seemed the perfect example of Karl Popper's conjectures and refutations. In 1957 Arthur Kornberg isolated a polymerase enzyme from *Escherichia coli* bacteria that would synthesize DNA *in vitro* – conjectured and confirmed. Well, confirmed yes; but was the conjecture true? John Cairns was a doubter and he set about searching countless quantities of *E. coli* bacteria attempting to find a mutant strain of *E. coli* lacking Kornberg's enzyme but still capable of reproducing itself – that is, replicating its own DNA. His attempt at refutation was successful and Kornberg's enzyme though originally confirmed as a DNA synthesis enzyme turned out to have a different function in the natural setting of a cell. Perhaps this a minor story in the history of biology but the broader history of molecular genetics can take on

epic proportions. One of the best accounts of this history is suggestively titled, *The Eighth Day of Creation* (Judson, 1979). The less than subtle allusion is of course to the *Bible's* account of the seven days of creation.

The stories of scientific success were important beyond their explicit purpose of teaching scientific concepts. The stories bolstered student confidence in science. For example, when we did those DNA extraction experiments, the truth is that we students only understood portions of what was being done. If any of us had been vigorously pressed to answer how we knew that sticky stuff on the glass rod was <u>really</u> DNA, we would have struggled to answer. We knew in part but much else we accepted on the basis of scientific authority vested in the professor and laboratory instructor. <u>Why wouldn't we? We had heard the stories</u>. It never occurred to us that we had <u>faith</u> in science and scientists. Several years later the basis for that faith was dramatically reaffirmed for me. My wife and I were expecting our first child. As it happened, Alex was born several weeks pre mature and suffered from fetal respiratory distress syndrome. Upon birth his lungs had not opened fully and the fetal duct that allows blood to bypass the lungs of an unborn baby had failed to close at birth. We were living in San Diego at the time and Alex was immediately transferred from the hospital of his birth to the University of California-San Diego teaching hospital. This hospital had a neonatal research ward where one of the specialty interests by God's grace happened to be fetal respiratory distress syndrome. Perilous days followed but Alex pulled through with no lasting ill effects. Had he been born only a few years earlier and with this syndrome, he would not have lived through his first twenty-four hours. Why wouldn't I acknowledge the authority of science?

The excitement I felt as a student of science and the power I witnessed with my son's full recovery are grounded in the powerful ideas and methods that science has uniquely contributed to our culture in the 20th century. Cultural historian O. B. Hardison remarked that "no examination of modern culture can exclude the influence of science and technology, and one that underestimated their influence would be irresponsible" (1989, p. xi). There is cultural capital in science that properly belongs to everyone. The science community will endorse this perspective and this is what "science for all" should at the least be about. The science community, however, is not always so noble. For example, the National Academy of Science

in its attempt to ward off religious incursions in the public square told American science teachers:

> In a nation whose people depend on scientific progress for their health, economic gains, and national security, it is of utmost importance that our students understand science as a system of study, so that by building on past achievements they can maintain the pace of scientific progress and ensure the continued emergence of results that can benefit mankind (1984, p. 6).

The fact that this statement so blithely ignores the complex and ambiguous relationship between science and technology and between science and economic development (Drori, 1996), casts doubt on the Academy's sincerity. Indeed some would see in this statement an attempt by the science community to protect its privileged status to control the discourse in certain segments of the public square, particularly the schools. Lynda Birke (1990) asks whether the drive to educate the public about science is merely an exercise in public relations and labor recruitment? Who will really benefit? For a profitable discussion of these questions see Bishop (1995), Goodstein (1995), and Kevles (1995).

Anti Science Sentiment

Setting aside the contentious question of motive, the science community in its desire that the public understand and esteem science finds itself concerned with the alleged low levels of public scientific literacy. There is no point in once again rehearsing well known statistics (see Yager et al., 1996) accept to say that *Science & Engineering Indicators—1996* has very recent American data and the 1996 National Research Council report has comparative data on industrial nations. Suffice it to say, the scientific community which is largely responsible for financing surveys of public scientific literacy is not very happy with the figures. Nor has it been for a very long time. Layton et al (1993, p. 8) report that, "by the opening of the twentieth century laments were common about the failure of science to be assimilated into the common understanding." What distinguishes the last twenty years is a slow rise in what the scientific community has called anti science and irrationality.

Science & Engineering Indicators—1996, funded by the National Science Foundation (USA), is an important document on the current status of American science and engineering. The writers chose to highlight the fact that about 40 percent of Americans express much

confidence in the science community which is higher than confidence placed in the US Supreme Court. The other side of this fact, however, is that 60% of Americans are less than confident in the science community. Some 30% are less than sure that the benefits of scientific research outweigh the harmful results and a full 10% view science as more harmful than beneficial. These statistics, strikingly inconsistent with America's status as a scientific giant, have been fairly steady since the late 1970s when the eminent historian of science Lynn White (1979, p. 73, emphasis added) asked:

> Why has the level of antagonism toward science so clearly risen in our society during the past decade or so, to a point where many professionals feel not only angered at the mixed public appreciation of their efforts but also threatened by declining support of their researches?

To which he answered,

> The problem is public alienation. For a variety of reasons a significant part of the general public has become distrustful of those goals, values and methods [of science].

White's article appeared in the inaugural issue *Science 80* which was a magazine published by the American Association for the Advancement of Science (AAAS) for the specific purpose of improving the American public's understanding of science.

Through the 1980s, however, the science community perceived continued outbreaks of dissatisfaction with science in the form of anti-evolutionism and spiritualism (Holton, 1992). In the 1990s scientists found that anti-science was no longer confined to K-12 schools and unscientific parents. Anti-science had infected the very institutions of rationality, the universities. This perception motivated Gross and Levitt to write their book, *Higher superstition: The academic left and its quarrels with science*, published in 1993. Two years later, Gross and Levitt working with the New York Academy of Sciences brought together,

> about 200 worried scientists, doctors, philosophers, educators, and thinkers... [because] there is a growing danger, many said, that the fabric of reason is being ripped asunder, and that if scientists and other thinkers continue to acquiesce in the process, the hobbling of science and its handmaidens - medicine and technology among them - seems assured. (Browne, 1995, p. E2, emphasis added)

The meeting was titled, "The Flight from Science and Reason." Those committed to ripping reason asunder included feminists such as Sandra Harding (1993) who raises questions about the nature of objectivity in science. They include Molefi Asante (1992) and Ivan Sertima (1987) who are proponents of Afrocentrism and concepts of African rationality. There are

multiculturalists in general (e.g., Grant, Sleeter, & Anderson, 1986). Still worse are the strong proponents of the social study of science such as Bruno Latour (1987) and Steve Fuller (1991) who advocate a social constructivist view of scientific knowledge. Worst of all the offending academics are the critical theorists such Henry Giroux who writes about critical pedagogy (e.g., Giroux & McLaren, 1989) and the literary critic Stanley Fish who is the editor of the radical cultural studies journal, *Social Text*.

"Can science get any respect?" asked Kevin Finneran (1996, p. 95), editor of *Issues in Science and Technology*. One would hope so but in the same year that *Higher Superstitions* was published, the eminent physicist Freeman Dyson published, "Science in Trouble," in which he commented that "attacks against science are likely to become more bitter and more widespread in the future..." (1993, p. 524, emphasis added). Perhaps with that ominous prediction in mind, one scientist recently attempted to deliver a "knock out" punch to the radical social constructivists. Alan Sokal is a physicist at New York University and he wrote a manuscript titled, "Transgressing The Boundaries: Towards A Transformative Hermeneutics Of Quantum Gravity" (1996b), which he submitted to *Social Text* for review and possible publication. Subsequently *Social Text* published the article only to have Sokal within days of the publication announce that the article was a hoax. Sokal had submitted a nonsense manuscript which by its acceptance for publication exposed the radicals as academic charlatans, in his opinion of course. In his own words:

> For some years I've been troubled by an apparent decline in the standards of intellectual rigor in certain precincts of the American academic humanities. But I'm a mere physicist: if I find myself unable to make head or tail of *jouissance* and *différance*, perhaps that just reflects my own inadequacy. So, to test the prevailing intellectual standards, I decided to try a modest (though admittedly uncontrolled) experiment: Would a leading North American journal of cultural studies -- whose editorial collective includes such luminaries as Fredric Jameson and Andrew Ross -- publish an article liberally salted with nonsense if (a) it sounded good and (b) it flattered the editors' ideological preconceptions? The answer, unfortunately, is yes. (Sokal, 1996a, p. 1)

I doubt that Sokal landed a knock out punch but there is no doubt about the ruckus that ensued.[2] Moreover, Sokal may not respect the people at *Social Text* but he must worry about

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[2] Those interested in this strange affair should consult web cite <http://www.nyu.edu /gsas/dept/physics/faculty /sokal/index.html> for a full account including plus Sokal's original article. Already one university has

them and other radical social constructivists. Why else would he even give them a second thought? Indeed, what has happened to the scientific community that one of its distinguished members finds enemies in academe that must be combated in such a non academic fashion? This is a question that will surely occupy the sociologists of science for sometime to come.

Scientific Positivism

I do not disagree that there are extremes of social constructivism antithetical to science and to the celebration of science that I have offered. To some extent Alan Sokal has done all scholarship a favor by exposing the excesses of extremist social constructivism. One should also be concerned that legitimate criticism of the scientific community not be lost in these intellectual skirmishes involving extreme positions. It is in the scientific community's best interests to heed legitimate criticism. "If scientists willingly join the cultural debate about science, science can grow in stature" (Finneran, 1996, p. 96). If they do not, the science community will by default affirm Martin Heidegger's quip that scientists do not think.

As I tried to convey in my celebration of science, science can be exhilarating. It is exhilarating to realize that one can know so much about the natural world and to feel that one can discover so much more. Earlier I also hinted that the scientific community should look within itself as the community considers the current problems with the public and science. Along with being exhilarating, science is also seductive. It can seduce one to the naïve materialism that what one knows by science is fundamental reality, when in fact the debates over the nature of scientific knowledge with respect to ontological realism are as current today as they ever were (see, e.g., Hawking & Penrose, 1996). Science can also be deceptive. It can deceive one into thinking one has privileged knowledge. Indeed, the cultural point of discussion that I think is most crucial is the point of epistemological position. How should the scientific community seek to position science with respect to other domains of knowledge in the public square? For the better part of the 20th century that question has been answered by a philosophy of logical positivism which sought to "banish metaphysics from philosophy,

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planned a follow up conference titled, "Science and its critics: A meeting to promote dialogue between the 'two cultures,'" to be held at the University of Kansas, February 28-March 1, 1997, where Sokal is to be the featured speaker.

because its theses cannot be rationally justified" (Holton, 1992, p. 45) leaving sense perceptions as the only admissible basis of human knowledge and precise thought. In philosophy positivism is yesterday's news, a failed project (Walsh, 1967), but what might be called scientific positivism (Gilmer, 1995) or colloquial positivism hangs on. Scientific positivism roughly represents a classical view of realism, philosophical materialism, strict objectivity, and hypothetico-deductive method. Though recognizing the tentative nature of all scientific knowledge, scientific positivism imbues scientific knowledge with a Laplacian certainty denied all other disciplines, thus allowing the scientific community to make an *a priori* status claim with regard to knowledge. Thus the scientific community projects in the public square a pyramid view of epistemology (Figure 1) with the natural sciences, of course, occupying the top most position.

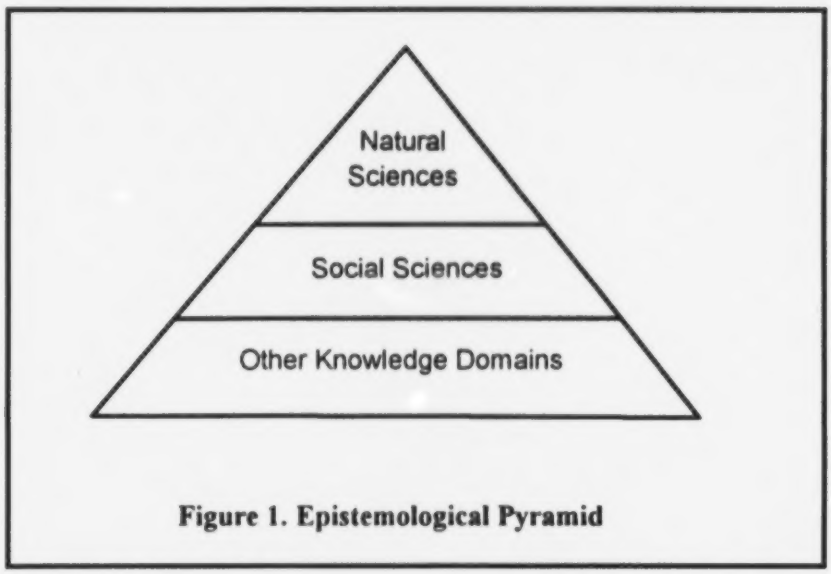

Figure 1. Epistemological Pyramid

This view of scientific knowledge has long been endemic in the schools (Duschl, 1985; Nadeau & Desautels, 1984; Settle, 1990; Smolicz & Nunan, 1975) and is what gives rise to the cultural critics' charge of hegemony (Cobern & Aikenhead, in press; Harding, 1993). Though philosopher of science Michael Ruse was speaking specifically of evolutionary biologists, I think his remark is too often apropos of the general scientific community: Scientists "tend to treat evolution as a kind of religion.... Evolutionists tend to be as fervent

true Believers as Creationists..." (Ruse, 1993, p. 353). The term "true believer" was made popular by the blue collar philosopher Eric Hoffer (1966) whose book titled, *The True Believer*, investigated the nature of mass movements. Science has the characteristics of a mass movement; and:

> It can be argued that technology and scientific positivism constitute the dominant ideology of Western civilization today. Technology has indeed become, as Heidegger noted, the metaphysics of our age, a totalistic form of secular religion ultimately incompatible with the existence of rival, nontechnological assumptions, beliefs, or thought systems. (Garrard & Wegierski, 1991, p. 611)

Unfortunately, this ideology couples the science community with what I call the Four Western Imperatives of the late 20th century:

1. The Imperative of Naturalism - All phenomena can ultimately and adequately be understood in naturalistic terms.
2. The Scientistic Imperative - Anything that can be studied, should be studied.
3. The Technocratic Imperative - Any device that can be made, should be made.
4. The Economic Imperative - Material well being is the highest good.

Further discussion of these statements is beyond the scope of my topic. What I want to point out is that these imperatives lead to a blinkered view of life that fosters a cynicism that soon gives way to longing. Moreover, with regard to science, the first two imperatives cut the very ground from beneath science. Philosopher Hendrick Hart (1980, p. 6) observed that "the positing of the ultimacy of rationality unmasks itself as a belief which cannot be rationally justified... Indeed, in our times belief in reason is increasingly characterized as a commitment to reason which itself lacks rational grounds." Similarly, in our times belief in science is increasingly characterized as a commitment to science which itself lacks rational grounds. And, that claim to epistemological privilege has not gone unnoticed. The radical relativism that no so severely vexes people like Sokal, Gross, and Levitt is a classic case of having sown to the wind, one now must reap the whirlwind. In other words, the radical social constructivists have simply turned empiricism's searing analysis back upon the scientific community itself; and the more the scientific community protests this ill treatment, the more vulnerable it looks.

An Alternative View of Science and the Public

Yes, the science community does need to re vamp its conceptualization of the public's understanding of science if the public is to be well served and if science is to prosper. We can begin, however, with a celebration.

(1) We can affirm that science is part of the cultural heritage that belongs to all people. The exhilaration that I felt as a student of science should be available to all who wish to avail themselves of it. The benefits to my family should be benefits available to all; that is, all who wish to avail themselves of these benefits.

(2) Science is part of the cultural heritage that belongs to all people, but it is not the sole constituent of that heritage, neither is there any consensus on its rank ordered position in that heritage. Historian O. B. Hardison (1989, p. 70-71) noted that, "The science of the late twentieth century asks man to understand himself in the light of his own reason detached from history, geography, and nature, and also from myth, religion, tradition, the idols of the tribe, and the dogmas of the father." This request is an invitation to alienation. Doing this not only places science at the top of the epistemological pyramid (Figure 1), it removes science from the pyramid. Science has powerful ideas such as the conservation of energy, homeostasis, ecological systems, change through time, uniformity, and empirical-experimental inquiry. There are also other powerful ideas such as freedom, democracy, rule of law, human dignity, moral rectitude, social solidarity, and transcendence. What the scientific community must understand about people, is that science along with history, art, language, technology, and religion are pendants on a wonderfully intricate mobile of everyday thought, "touch one and the rest tremble and change position in sympathy" (Hardison, 1989, p. xiv).

(3) There are legitimate differences between the interests of science and public's interest in science. These differences will preclude any consensus on science's rank ordered position in our cultural heritage. The template for school science through undergraduate education, however, has traditionally served the interests of science. In science education it is common to hear of the scientific "pipeline" (Figure 2). This is a metaphor for a flow system that

delivers scientists and science related graduates; and, as such, this is a system where the educational experiences of the many are dictated by the needs of a very few. Even when interdisciplinary science curricula are adopted they often continue to serve the interests of science. These curricula acknowledge that students have other disciplinary interests but do so for the purpose of manipulating those interests to meet the traditional objectives of science education. Thus, these other disciplinary interests become paths to science and the paths are clearly secondary to the destination which is science. Moreover, one is likely to find that the destination, science, will occasionally critique those other disciplinary paths and starting points. For example, we may hear that the starting point is very distant from science and it will be difficult to build this path but the community of science and science teachers must try for the good of the learners and for the public. What is not an option is the critique of science by those other disciplinary interests that science education is manipulating. This is a problem against which the Science-Technology-Society curricula are making some inroads.

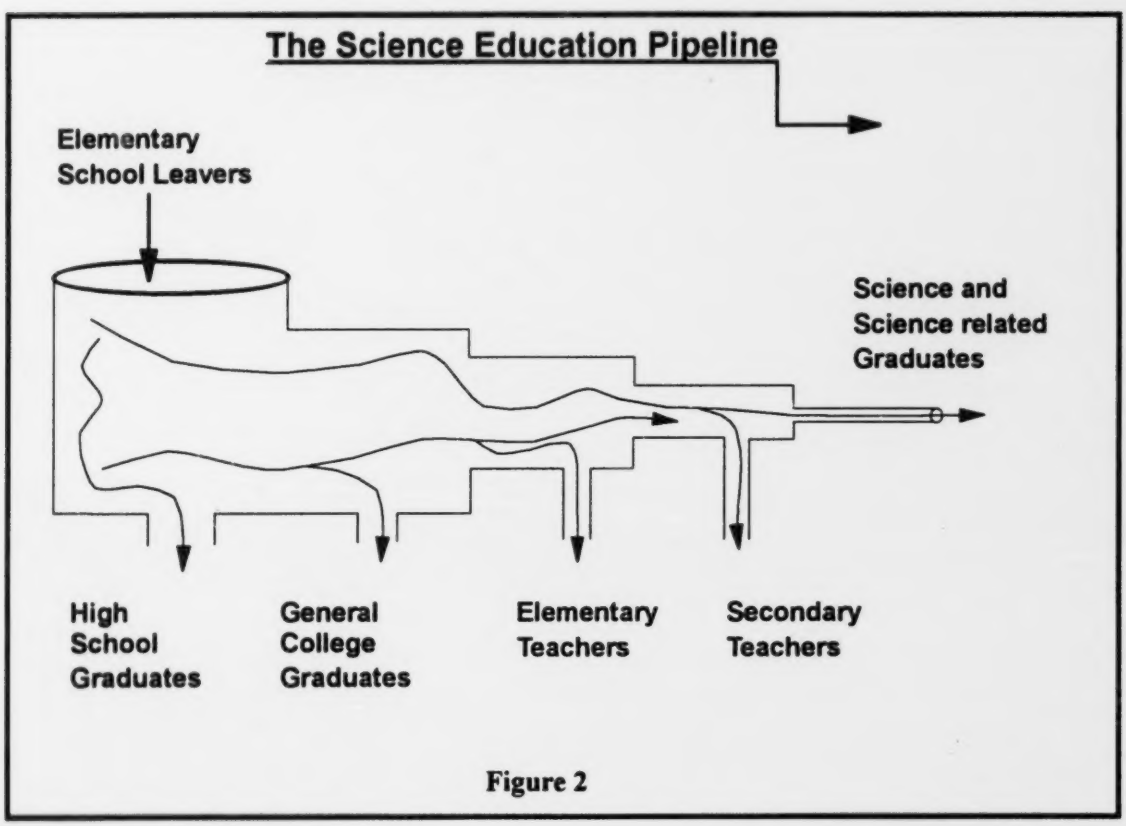

Figure 2

(4) Moreover, the public's variable interests in science will inevitably lead to different conceptualizations and valuations of science. Earlier I mentioned being a student during the height of the Viet Nam war. Many of my friends had a very different valuation of science because of what they perceived as an unholy alliance between the community of science and a military-industrial complex that developed and produced weapons. The rhetoric of values neutrality was not tenable when the science community having taken credit for such things as the "Green Revolution" now denied any responsibility for "Agent Orange" and the like. Thus they place a low value on science and sometimes a negative value.

There are, however, more common examples than this one. In a recent study researchers talked with ninth graders about their views on nature. The objective was to gain insight on the extent to which science was used in everyday thinking (Cobern, Gibson, & Underwood, 1995)[3]. One of the students, Ann, spoke of nature as something one can know about through science.

> **Ann**: Nature is knowable... We can learn to understand many things about nature through personal experience, school and science. Science itself provides us with technology which in turn increases our scientific knowledge. Technology helps provide us with many wants which, of course, increases our pleasure. It also uses resources. (ATG.n6, Narrative in Cobern et al., 1995, p. 24)

This appreciation of science, however, is not where her discussion with the researchers began. Note the emphasized words.

> **Ann**: <u>To me, nature is beautiful and pure because it is God's creation</u>. Nature provides both <u>aesthetic and emotional pleasure</u> and I need it for self renewal. I like to go where you can't see any influence by man. When I'm out <u>in nature I feel calm and peaceful</u>. It is a <u>spiritual feeling</u> and it helps me understand myself... This leads me to ask questions that I'd like to find answers to. The <u>pleasure</u> I get from nature is enhanced by the mysteries I see in it. (ATG.n6, Narrative in Cobern et al., 1995, p. 24, emphasis added)

Ann's conceptualization of the natural world has significant aesthetic and religious elements. Nature in her view is something friendly that you can joyously be part of.

Now consider Mr. Hess. He is Ann's physical science teacher and he who sat for the same research interview as did Ann. He began his discussion in marked contrast to Ann.

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[3] The research was funded by a National Science Foundation grant (RED # 9055834).

> **Mr. Hess**: Nature is orderly and understandable. The tides and the rotation of the earth, the seasons and so forth are examples of order in nature. That the planets and the stars are governed by physical forces and any deviations are simply because we have not yet discovered the other part of nature's orderliness. According to chaos theory even things that appear to happen randomly have patterns. I think that everything has patterns.... As a science teacher I feel that with enough scientific knowledge we all things are understandable.... I think that the more we understand about matter itself, and the more we know about how to make things, the more predictable nature will be. Scientific or reductionistic thinking is very powerful. I feel that once we know enough about the minutia of the world, breaking it down by using the scientific method, scientists tearing it apart and analyzing the parts of nature and seeing how they interact, that we will be able to predict just about anything about nature. (WWC.t6, Narrative in Cobern et al, 1996, emphasis added)

In contrast to Ann, her science teacher's conceptualization of nature showing the integration of scientific themes is essentially monothematic. It is classical scientific positivism and could hardly differ more from his student, Ann. Figure 3 is a generalized concept map of Nature drawn from interviews with high school science teachers and college science professors. Although our studies show marked differences between biologists and physicists (Cobern et al, 1996), they are consistent with respect to the centrality of science in their thinking. The ninth grade students of our studies and the non science college majors showed substantial variability in their conceptualizations of nature and integration of scientific themes and concepts. Figure 4 is a generalized concept map of Nature drawn from interviews with students and shows the extent of variation.

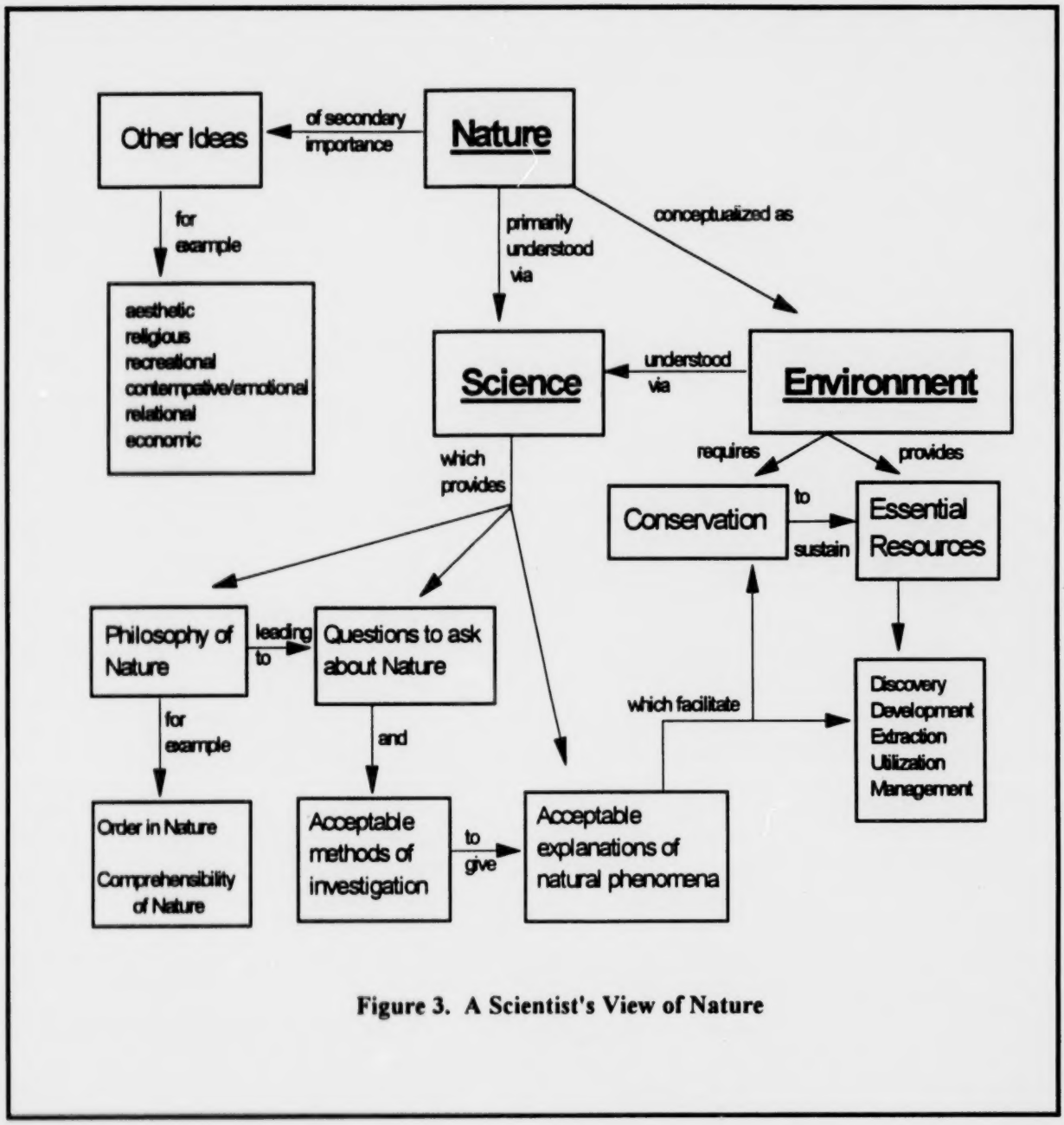

Figure 3. A Scientist's View of Nature

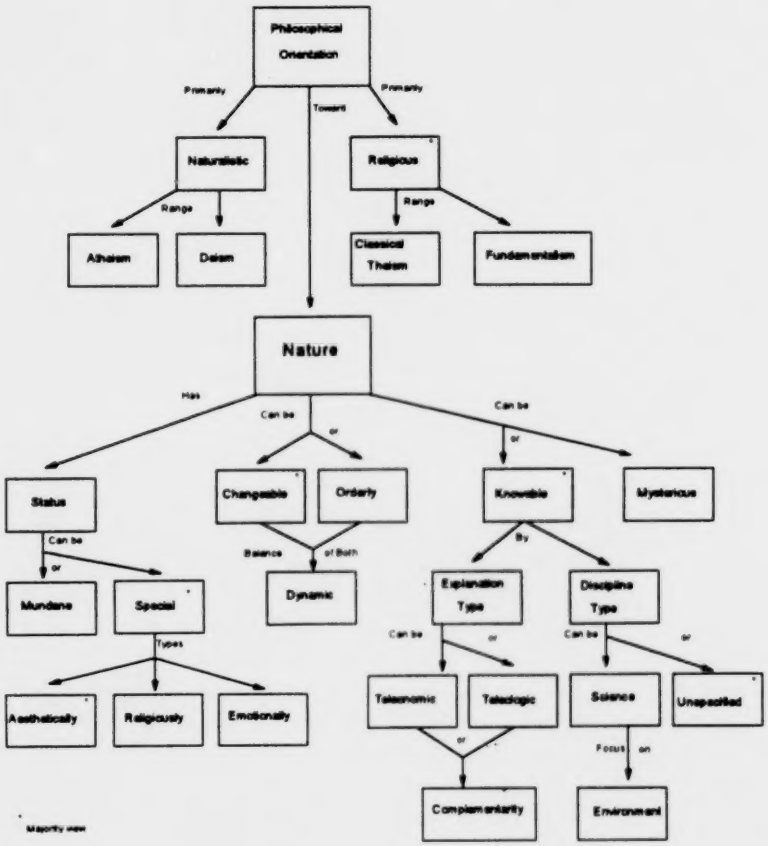

Figure 4. Non Scientists' Views of Nature

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Occasionally one finds a student who talks very much like a science teacher or professor. Most do not, but this does not mean that the students are unscientific. For example, it is possible to have an aesthetically oriented view of life that incorporates scientific thinking. Not aesthetics manipulated for the purposes of science, however. I have in mind Pythagorean viewpoint where the artistic person would value learning science because of the beauty and elegance of its representations.. Near the end of Kepler's *Harmony of the World* (1619) he wrote, "I thank thee, Lord God and Creator, that you have permitted me to see the beauty of your work and creation." J. B. S. Haldane in this century wrote:

> As a result of Faraday's work you are able to listen to a wireless. But more than that, as a result of Faraday's work, scientifically educated men and women have an altogether richer view of the world. For them, apparently empty space is full of the most intricate and beautiful patterns. So Faraday gave the world not only fresh wealth but fresh beauty.

Benoit Mendelbrot's pioneering work with fractal geometry is another area of science and mathematics where aesthetic elements have blurred traditional disciplinary boundaries. My own view is that the different conceptualizations of science should be encouraged; and in addition to the aesthetic, these could be economic, religious, contemplative, environmentalist and others.

(5) The community of science can help itself by engaging the public in good-faith discussions about these different conceptualizations and valuations of science. By good-faith I mean that the scientific community does not presume that it holds a privileged position in the discussion. For example, a typical scientist to use a Kuhnian term is a puzzle solver who looks at a scientific solution with the pride of mastery as if to say, "Here is an important natural phenomenon and I know how it works!" The scientist should not assume, however, the moral neutrality of his or her discovery. During the Viet Nam era, and I think this continues today, the public is very interested in the moral implications of scientific work. The Human Genome Project or fetal tissue research are only two of many examples. In a very informative study Tobias (1990) found that for some well educated people, science lacks interest because it appears to them that scientists do not ask important questions such as about the morality of what they do.

(6) An important point of discussion especially with respect to school science, is the compatibility of science with very different perspectives. It is important to acknowledge that not all ideas and worldviews that people hold will be compatible with science. It is also important to recognize that learning science in even the most enlightened of settings will bring about change. The important question is about when change is warranted and when it is not.

Concluding Remarks

So, yes, the science community does need to re conceptualize the challenge and re-examine its assumptions about the public understanding of science. The science community's historic perspective on the public is grounded in the legitimate interests of science; but, the promotion of the public understanding of science needs to be grounded in the public's legitimate interests in science. Professor John Polkinghorne, president of Queens College, Cambridge, who is a physicist and Anglican priest, recently made the following remarks in *Scientific American*:

> Everyone has a metaphysics – a worldview – just as all people speak prose, whether they are aware of it or not. Science can and should contribute to that worldview, but it should by no means monopolize it. Unless you are one of those biologists so flushed with the recent success of your discipline that you are moved to claim that 'science is all,' you will want to locate scientific understanding within a wider view of knowledge that gives equally serious consideration to other forms of human insight and experience" (Polkinghorne, 1996, p. 121, emphasis added).

It is time that the science community and school science education began to do just this: to locate science within a broader view of knowledge.

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